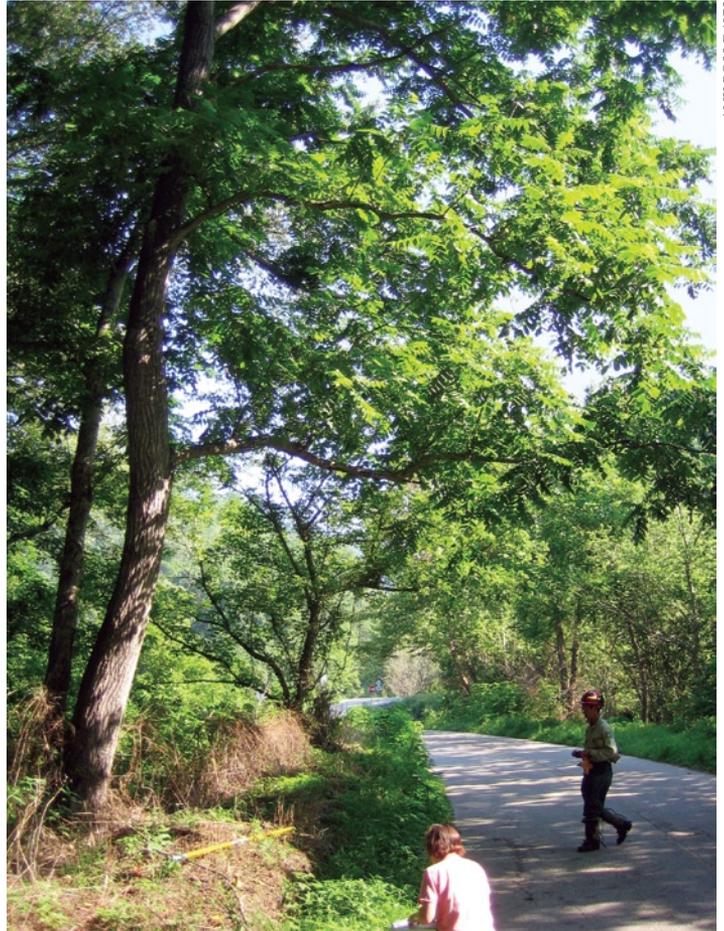


The Peril and Potential of Butternut

Keith Woeste and Paula M. Pijut

Butternut (*Juglans cinerea*), also known as white walnut because of its light-colored wood, is a short-lived, small- to medium-sized tree (40 to 60 feet [12 to 18 meters] tall; 30 to 50 feet [9 to 15 meters] crown spread) (Fig. 1). Butternut's native range includes most of the northeastern United States and southern Canada from New Brunswick to Georgia, and west to Arkansas and Minnesota (Rink 1990; Dirr 1998) (Fig. 2). Butternut often grows in widely scattered clusters, with each cluster containing a few individual trees. It was never a highly abundant species (Schultz 2003), but for reasons that will be described later, it is even less common now than before. The former prevalence of—and appreciation for—butternut in the landscape is reflected evocatively by the many Butternut Hills, Butternut Creeks, and Butternut Lakes found across the eastern United States.

Butternut is a member of the walnut family (Juglandaceae), which includes many familiar nut trees including eastern black walnut (*Juglans nigra*), Persian or English walnut (*J. regia*), pecan (*Carya illinoensis*), and all the hickories (*Carya* spp.). How butternut relates to the other walnuts remains a puzzle. Early taxonomy placed butternut in its own section within *Juglans* (*Trachycaryon*), but more recent treatments place it with Japanese walnut (*J. ailantifolia*) and Manchurian walnut (*J. mandshurica*) in section *Cardiocaryon* (Manning 1978; Fjellstrom and Parfitt 1994), or with the New World walnuts (*Rhysocaryon*) (Aradhya et al. 2007). Butternut cannot hybridize with eastern black walnut, but it can hybridize with Persian walnut to form *J. × quadrangulata*, and with Japanese walnut to form *J. × bixbyi* (USDA-NRCS 2004). Of all the walnuts, butternut is considered to be



AMY ROSS-DAVIS

Figure 1. Researchers collect samples from a true butternut growing in Daniel Boone National Forest, Kentucky.

one of the most winter-hardy, to USDA Zone 3 (average annual minimum temperature -30 to -40°F [-34 to -40°C]).

Food, Furniture, and Forage

Butternut has a long history of usefulness. Native Americans extracted oil from the crushed nuts by boiling them in water, made syrup from the sap (Goodell 1984), and threw butternut bark (which contains toxins) into small streams to stun and capture fish. They

taught early European settlers how to make medicine from butternut bark, roots, and husks (Johnson 1884; Krochmal and Krochmal 1982). The inner bark of butternut and its nut hulls can be used to produce a yellow-brown dye. This dye was used most notably on some of the Confederate Army's Civil War uniforms, giving rise to the practice of referring to southern troops and their sympathizers as "butternuts" (Peattie 1950).

Butternut is valued economically and ecologically today for its wood and edible nuts (Ostry and Pijut 2000) (Fig. 3). The sweet, oily, edible nuts are used in baked goods and are also popular for making maple-butternut candy. Butternuts were often planted near homes on farmsteads for the use of the nuts. There has been limited selection of butternuts for nut quality and production (McDaniel 1981; Goodell 1984; Miliken and Stefan 1989; Miliken et al. 1990; Ostry and Pijut 2000), but a few butternut cultivars with large nut size and superior ease of cracking (e.g., 'Chamberlin' and 'Craxczy') have been propagated, and some of these are available from commercial nurseries.

The nuts are also an important food source for wildlife. In forests, butternut trees produce



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Figure 3. Butternut fruits have thick husks covered with sticky glandular hairs. Inside the husk is an edible nut enclosed in a thick, hard shell that is elaborated with eight prominent ridges (Brinkman 1974; Flora of North America Editorial Committee 1993+).



NANCY ROSE

Figure 4. Butternut wood samples: (clockwise from upper left) bark, slab-sawn, quarter-sawn, and cross-section (note darker brown heartwood). From the Ralph F. Perry wood collection at the Arnold Arboretum.

seed at about 20 years of age, with good seed crops occurring every two to three years (Rink 1990). Open-grown trees, which benefit from more sun and less competition, can begin bearing as early as five years of age and bear annually under ideal conditions.

The sapwood of butternut is light tan to nearly white and the heartwood is light brown (Fig. 4). The wood is moderately hard, but workable; it saws and carves easily, finishes well, and resembles black walnut when stained. The commercial availability of butternut wood is now extremely limited, but quality butternut

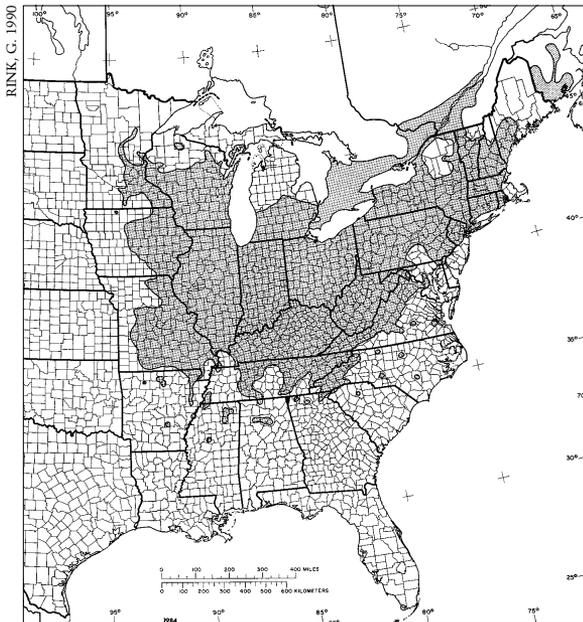


Figure 2. The native range of butternut.

RINK, G. 1990



Figure 5. The library at Grey Towers National Historic Site is paneled in butternut.

wood commands a high market price today for many uses including furniture, veneer, cabinets, paneling, specialty products such as instrument cases, interior woodwork, and fine woodworking. The library of Grey Towers, a National Historic Site near Milford, Pennsylvania, and formerly the home of Gifford Pinchot, the first chief of the United States Forest Service, is paneled entirely with butternut (Fig. 5).

A Deadly Disease Arrives

Sadly, a devastating canker disease has caused range-wide butternut mortality in recent decades and threatens the survival of the species. Unusual stem cankers were first observed on butternuts in southwestern Wisconsin in 1967 (Renlund 1971). A pest alert announcing butternut decline was issued in 1976 (USDA 1976), and by 1979, the fungus responsible for butternut canker disease, *Sirococcus clavigignenti-juglandacearum*, was described as a new species (Nair et al. 1979). Surveys of butternut trees in Wisconsin in the 1990s revealed that 92% were diseased and 27% were

dead (Cummings-Carlson 1993; Cummings-Carlson and Guthmiller 1993). By the early 1990s butternut canker was reported in Canada (Davis et al. 1992), and butternut is now considered an endangered species in that country. In 1992, the state of Minnesota placed a moratorium on the harvest of healthy butternut on state lands, and butternut is considered a species of special concern in all United States National Forests.

Although the origin of the fungus is uncertain (evidence suggests it may have come from Asia), it is believed to have been introduced into North America as a single isolate (Furnier et al. 1999). Butternut trees of all ages and sizes, regardless of site conditions, can be infected. The spores of the fungus are spread by rain splash and aerosols to adjacent trees where new infections originate at leaf scars, lateral buds, bark wounds, and natural bark cracks. Perennial cankers eventually develop on twigs, branches, stems, and even the buttress roots (Tisserat and Kuntz 1983). Cankers can be seen most easily if the bark is removed, revealing a sunken, elliptically-shaped region of dark brown to black stained wood, often with an inky black center and a whitish margin (Ostry et al. 1996) (Fig. 6). Cankers reduce the quality and marketability of the wood, and the girdling effect of multiple coalescing cankers eventually kills a host tree.



Figure 6. Healthy butternut (left), and tree with bark removed showing cankers (right).

While its spread to adjacent trees is understood, just how the fungus travels long distances to find new hosts remains a mystery. Several beetle species have been found on infected trees carrying fungal spores (Katovich and Ostry 1998; Halik and Bergdahl 2002), but it is not known which species (if any) carry spores over long distances. The fungus has also been found on the fruits of butternut and black walnut, causing lesions on the husks of both species (Innes 1998), which means that the movement of seeds can also spread the disease.

Conservation and Restoration of Butternut

There is no cure for butternuts once they become infected with butternut canker. In order to maintain butternut populations, conservationists must rely on a strategy of encouraging the growth of as many young, healthy trees as possible. The methods used include the management of regeneration (often by improving local habitats for seedling establishment) and reintroduction (for example, planting butternuts into suitable habitats from which they have been lost) (Ostry et al. 1994).

Butternut is a pioneer species, its seedlings require full sun to thrive (Rink 1990), and the presence of areas of exposed soil seems to benefit its establishment (Woeste, personal observation). These factors explain why young butternuts tend to be found now on road-cuts, steep terrain, fence-rows, old fields, clear-cuts, washouts, and the banks of swiftly flowing streams. The management of most hardwood forests—both public and private—favors minimal disturbance, so there are relatively few large, sunny openings for butternut seedlings to find a foothold. Browsing and antler rubbing by deer also limit the growth and survival of butternut seedlings in the few sites sunny enough to support regeneration (Woeste et al. 2009).

Butternut canker, of course, also plays an important role in reducing the natural regeneration of butternut (Ostry et al. 1994). A high



Figure 7. Foresters identified this healthy butternut in a central Indiana forest.

percentage of the mature butternuts growing in the eastern forest are cankered, and infected trees have limited energy reserves to put towards flower and fruit production. Because butternuts almost never self-pollinate (Ross-Davis et al. 2008b), when a high percentage of the trees in an area become diseased or are killed, the number of potential mates can be reduced to the point that adverse genetic and demographic consequences become likely (Geburek and Konrad 2008).

For all the above reasons and more, poor natural regeneration has been a hallmark of the butternut canker epidemic (Ostry and Woeste 2004; Thompson et al. 2006). Until we learn how to effectively assist natural regeneration of butternuts, reintroduction will be needed to restore butternut populations to the eastern



Figure 8. The trunk of a very old buart growing in central Indiana.

forest. Reintroduction, whether by afforestation (establishing plantations on old fields) or by supplemental planting in existing habitats, requires a ready source of seeds. Seeds from genetically diverse and locally adapted sources are preferred (Broadhurst et al. 2008). Because seed supplies from wild trees are so unreliable, numerous state and federal agencies as well as private nurseries have worked over the past 20 years or so to document the location and health of butternut trees that could be used as seed sources (Fig. 7). Others have collected and grown butternut trees to provide seeds that will be needed for reintroduction.

These collections constitute a germplasm repository for butternut, a living bridge to the future, and a method for preserving the genetic diversity of the species in the face of a devastating

population crash. Butternut collections must be conserved as living specimens growing in arboreta or other repositories because butternut seeds do not remain alive in long-term storage (even controlled-environment seed banks) unlike the seeds of many other species (Bonner 2008). Butternut can be propagated vegetatively by cuttings (Pijut and Moore 2002), through tissue culture (Pijut 1997; Pijut 1999), and by grafting.

The ideal seed source for butternut reintroductions would be an orchard of genetically diverse, locally adapted, and canker-resistant butternut trees. Starting in the 1980s, a small group of scientists began identifying, grafting, and growing butternuts that appeared healthy even though they were growing in locations with many dead or diseased trees (Ostry et al. 2003). It was assumed that these candidate trees had been exposed to the canker disease fungus, but because they remained healthy—or at least sufficiently healthy to continue to grow and reproduce—it was hoped that some of them would have genes for resistance to butternut canker. By the late 1990s, about 200 of these trees had been identified by Dr. Michael Ostry of the USDA Forest Service—North-

ern Research Station in St. Paul, Minnesota, and other colleagues.

Butternut or Buart?

By growing a large number of butternuts together in one location, Ostry and others were able to observe differences among these trees that had not been obvious at the time of collection. Differences in traits such as nut size and branch habit led him to wonder if some of the collected butternuts were, in fact, buarts (Ostry and Moore 2008). A buart (pronounced *bew-art*), also called a buartnut, is the common name for *Juglans × bixbyi* (hybrids between butternut and the exotic Japanese walnut) (Fig. 8). BUARTS were well known among nut growing enthusiasts in the United States and Canada, but virtually unknown by dendrologists and forest biologists

(Ashworth 1969). Buarts had probably already been growing unnoticed in yards and orchards for a generation when they were first described by Willard Bixby in 1919 (Bixby 1919).

Japanese walnuts were introduced into the United States around 1860 (Crane et al. 1937). In Japan, these walnuts were exploited as a food source by early tribal settlers (Koyama 1978), but never became an important commercial nut crop. By the late 1800s, Japanese walnuts had become popular among nut growers in the eastern United States because the kernels separate easily from the shell, and because some horticultural selections of Japanese walnut have an attractive and distinctively heart-shaped shell (Crane et al. 1937) (Fig. 9). Trees bearing heart-shaped nuts became known as heartnuts (technically *J. ailantifolia* var. *cordiformis*), and the hybrid combination of **butternut** plus **heartnut** results in the common name “buart”.

Cultivars of heartnut have been selected and named (Ashworth 1969; Woeste 2004), but heartnuts never became a market success in the United States, perhaps because the nuts, while exotic in appearance, tend to be bland tasting. Although Japanese walnut never became popular as a nut crop, it gained a permanent foothold in the New World by intermating with butternut. Over time, as buarts became more common and as the gene pools of butternut and Japanese walnut intermixed, it became almost impossible and certainly impractical for most people to distinguish butternuts from buarts (Fig. 10). As early as 1919, Bixby (1919) found that “[c]ertain Japan walnuts [are] so near like butternuts as to be readily mistaken for them. . . . [A]s far as the appearance of the nuts was concerned, the butternut could not be well separated from certain Japan walnuts.”

Buarts are remarkable hybrids. They stand out as exceptionally vigorous trees, sometimes exceeding 40 inches (102 centimeters) in diameter when mature (butternuts typically reach 12 to 24 inches [30 to 61 centimeters] in diameter). Buarts often bear enormous crops of nuts, and typically appear to be resistant to butternut canker (Orchard et al. 1982), although it is not certain that these trees truly are more resistant. It is easy to see why nut enthusiasts found buarts so attractive.



KEITH WOESTE

Figure 9. A distinctively shaped heartnut (center) surrounded by nuts of other (non-heartnut) forms of Japanese walnut. All the nuts in the photo came from Japanese walnuts grown at the National Clonal Germplasm Repository for *Juglans*, in Davis, CA.



PHOTO COURTESY SALLY WEEKS

Figure 10. Butternut (top row) and hybrid nuts (bottom row) with the husks removed look nearly identical.

As butternut populations dwindled and disappeared because of canker, buarts began to confound butternut conservation. Buarts were mistakenly identified as butternut survivors, and buarts planted in yards, parks, and cemeteries attracted seed collectors who gathered and sold the nuts to nurseries or through local markets, made them available through local conservation groups, or simply gave them away to friends and neighbors. Concerns about butternut’s status in the forest caught some unaware because there were so many large, healthy “butternuts” (really buarts) growing in farmyards all over the countryside. It is likely that landowners have planted many more buarts than butternuts over the past 20 years, since so many of the

Figure 11. Summary of Characteristics Distinguishing Pure Butternut from Hybrid Butternuts.

CHARACTERISTICS	BUTTERNUT	BUTTERNUT HYBRIDS
HABITAT	Forests, occasionally as a grafted tree or wildling	Parks, forest edges, farmyards, urban areas, planted trees, orchards
<i>1-YR-TWIGS</i>		
CURRENT-YEAR STEM	Olive green changing to red-brown near terminal, glossy, few hairs except immediately beneath terminal buds	Bright green to copper brown or tan, often densely covered with russet or tan hairs, especially near terminal buds. Pale green near terminal bud
TERMINAL BUD	Beige in color; longer and narrower than hybrids, and the outer, fleshy scales more tightly compact.	Pale green to tan or yellowish in color, wider and squatter than <i>J. cinerea</i> . Outer fleshy scales more divergent than butternut and often deciduous.
LATERAL BUD	Vegetative buds are elongated (sometimes stalked) and somewhat angular, creamy white to beige in color	Vegetative buds are rounded, and green to greenish brown in color.
LENTICELS	Small, round, abundant, evenly distributed, sometimes elongating horizontally across the branch (perpendicular to the stem axis)	Large, often elongating laterally down the branch (parallel to the stem axis) on 1-yr-wood, patchy distribution. On 3 and 4-yr-wood, lenticels often form a diamond pattern as they become stretched both transversely and longitudinally
LEAF SCAR	Top edge almost always straight or slightly convex; scar usually compact	Top edge almost always notched; often with large, exaggerated lobes
PITH	Dark brown	Dark brown, medium brown or even light brown
<i>MATURE TREE</i>		
BARK	Varies from light grey and platy to dark grey and diamond patterned in mature trees. In older trees, fissures between bark ridges may be shallow or deep but are consistently dark grey in color.	Silvery or light grey, rarely darker. Fissures between bark ridges moderate to shallow in depth and often tan to pinkish-tan in color.
LEAF SENESCENCE	Leaves yellow and brown by early-mid autumn, dehiscing in early to mid autumn.	Leaves often green until late autumn, dehiscing in late autumn or may freeze green on the tree.
CATKINS	5–12 cm in length at peak pollen shed	13–26 cm in length at peak pollen shed
NUT CLUSTERS	One or two nuts per terminal in most clusters, sometimes 3–5, rarely more.	Usually 3 to 5 per cluster, sometimes as many as 7.

remaining butternut trees have low vigor because of the effects of butternut canker and because butternuts, even when healthy, usually only produce a crop every two to three years (Rink 1990).

For butternut, the existence of these hybrids presents something of a dilemma. On the one hand, buarts represent the dilution and potential loss of a distinctive native species with deep cultural connections and a complex quilt of ecological roles that evolved over many hundreds of thousands of years. On the other hand, hybridization is a common theme in plant evolution (Wissemann 2007), and for butternut, hybridization could represent a way forward, especially if it is determined that all butternuts are completely susceptible to butternut canker (something that is far from certain at this point). What role hybrids will play in butternut recovery remains to be seen.

Detailing the Differences

Whatever the possible uses of buarts, by 2003 it became clear to researchers that they needed reliable mechanisms to distinguish buarts from butternuts (McIlwrick et al. 2000; Ostry et al. 2003; Michler et al. 2005). The first task was to describe the two parental species. Published descriptions of the vegetative and reproductive tissues of butternut, Japanese walnut, and the hybrids are often brief, and based on an unknown number of samples of unidentified provenance. By surveying published descriptions of butternut, especially those made before the introduction of Japanese walnut to the United States or before hybrids had an opportunity to become widespread, a clearer picture of the morphology of butternut and Japanese walnut emerged (Ross-Davis et al. 2008a). To verify our findings, we examined old butternut specimens at the Herbarium of the Missouri Botanical Garden. These long-preserved samples provided additional certainty that what we saw in the wild today matched what was collected over 100 years ago. We also obtained authenticated samples of Japanese walnut from the National



Figure 12. Twigs of butternut (top and bottom), Japanese walnut (upper middle,) and buart (lower middle). The shape of the lenticels is characteristic of each type.

Clonal Germplasm Repository in Davis, California, for comparison.

Armed with the best possible descriptions of butternut and Japanese walnut, we had to conclude that trees with intermediate traits were buart hybrids. After examining a large number of samples we developed a list of characters that can be used in combination to separate butternut and hybrids (Woeste et al. 2009) (Fig. 11). After a few years of observing these traits in the field we have trained our eyes and now find that most hybrids are fairly easy to spot, though for more complicated cases a careful examination is needed to make a determination. (Fig. 12)

At the same time, we began development of a series of DNA-based tools for identifying butternuts and hybrids (Ross-Davis et al. 2008a). The DNA markers are being used in both the United States and Canada to identify true butternut seed sources. To understand the genetic diversity of butternut, we developed DNA-based markers called microsatellites, and used these to evaluate samples of butternuts from five locations spanning the upper south and midwestern United States. To our relief, we learned that the genetic structure and neutral genetic diversity (diversity at the DNA level that is not associated with genes) of the current generation of large, standing butternuts was quite similar to that of black walnut, a much



Figure 13. Young butternut trees are screened for canker resistance at the Hardwood Tree Improvement and Regeneration Center in West Lafayette, Indiana.

more common related species (Ross-Davis et al. 2008b). This observation held out hope that it was not too late to begin to collect and preserve the genetic diversity of butternut.

Armed with new DNA-based markers, and support from The Nature Conservancy and the USDA Forest Service – State and Private Forestry, a small group of scientists and collaborators spent 2008 collecting butternut seeds as part of a long-term gene conservation program. A permanent home for the seedlings that will grow from these seeds is envisioned in western Iowa, sufficiently distant from sources of butternut canker it is hoped, to ensure the collection will be safe. These trees represent one of several collections that will reconstitute the future for butternut.

A final note of good news is that an evaluation of candidate canker-resistant butternuts using our DNA-based methods confirms that

many of the trees are truly butternuts and not hybrids (Woeste, unpublished data). Recently, pathologists proposed protocols for inoculating and testing candidate trees to determine if these are truly resistant to butternut canker (Ostry and Moore 2008) (Fig. 13). If future pathology studies demonstrate that some candidate trees contain useful levels of resistance to butternut canker, an aggressive program of breeding will be undertaken to transfer the resistance genes into butternuts from all across the species' range. The goal will be to produce seed orchards of genetically diverse, regionally adapted, disease-resistant butternuts for reintroduction to areas of the eastern forest where butternut has disappeared. Learning how to reintroduce and sustain viable populations of trees into habitats from which they have been lost remains an important and ongoing challenge (Broadhurst et al. 2008; Geburek and Konrad 2008).

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